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USSR REPORT

PHYSICS AND MATHEMATICS

No. 85

CONTENTS

CRYSTALS AND SEMICONDUCTORS

LASERS AND MASERS

SPECTRAL MANIFESTATION OF MOBILITY LIMIT FOR EXCITONS IN $CdS_{1-x}Se_x$

PERMOGOROV, S. A., REZNITSKIY, A. N., VERBIN, S. Yu. and LYSENKO, V. G.,
Physico-Technical Institute imeni A. F. Ioffe, USSR Academy of Sciences

[Abstract] A study was made of excitons (localized concentration fluctuations) in $CdS_{1-x}Se_x$ solid solution and of the polarization of their luminescence. Specimens of hexagonal crystals were excited by polarized radiation from an Ar^+-laser or a dye (coumarin 152) laser. Luminescence from cleavage planes or growth faces perpendicular to the optical axis was recorded and the degree of its polarization measured as the ratio $\rho = (I_{||} - I_{\perp})/(I_{||} + I_{\perp})$ ($I_{||}$, $I_{\perp}$- luminescence intensities in polarization respectively parallel and perpendicular to polarization of the exciting light). These measurements revealed a dependence of the degree of luminescence polarization on the frequency of the exciting light. Polarization of luminescence, attributable to a random orientation and "latent anisotropy" of potential wells which localize an exciton, is in this case preceded by splitting of the Γ_5 exciton level without subsequent transfer of excitation from one well to another. The sharp decrease of polarization on the short-wave side of the spectrum corresponds to depolarization as a result of transfer of excitation from an initial level to a level in another potential well and is interpreted here as the beginning of exciton mobility, the probability of exciton migration increasing with higher excitation frequency. This mobility threshold also coincides with a sharp upward jump of luminescence intensity on the short-wave side. The decrease of polarization on the long-wave side of the spectrum cannot be explained by migration of excitons, but perhaps by a change in anisotropy. Two possible mechanisms are proposed here. One is interaction of adjacent potential wells. Another is deepening of localization in deep but narrow potential wells so that only holes become localized, while electrons have an averaging effect because of the large radii of their orbits. The authors thank Ye. L. Ivchenko, G. Ye. Pikus, E. I. Rashba and V. B. Timofeyev for discussing the results. Figure 1, references 7: 4 Russian, 3 Western.
[45-2415]

EFFECT OF ONE-DIMENSIONAL DISORDER ON EXCITON STATES IN SEMICONDUCTOR
SOLID SOLUTIONS

MASLOV, A. Yu., SUSLINA, L. G., ARESHKIN, A. G., MELEKHIN, V. G. and
FEDOROV, D. L., Physico-Technical Institute imeni A. F. Ioffe, USSR
Academy of Sciences

[Abstract] There are two kinds of disorder in semiconductor solid solutions:
three-dimensional disorder due to concentration fluctuations and one-
dimensional disorder due to stacking defects produced in the structure when
two compounds with different crystal lattices are mixed, both disorders
giving rise to a random potential distribution and to a blurring of band
boundaries. A theoretical solution to the three-dimensional problem is
necessarily approximate, but the one-dimensional problem can be and has been
solved exactly. As a test case the authors consider the effect of one-
dimensional disorder on the exciton states in the $Zn_{1-x}Mg_xS$ system over the
entire $0 < x < 0.12$ range of existence of sphalerite-wurtzite phase transi-
tion. The disorder here was measured by two methods, birefringence and
exciton spectroscopy at low temperatures (77 and 2 K). The location and the
widening of the exciton ground line in the reflection spectrum vary as
functions of the magnesium content x, the location of this line shifting
from 3.87 eV at $x = 0$ to 3.96 eV at $x = 0.12$ and its half-width peaking
at $x = 0.056$ and $x = 0.062$ to approximately 20 meV. This is confirmed
theoretically on the basis of the Schroedinger equation of motion for an
exciton in a one-dimensional random potential and the equation

$$\frac{dE_A}{dx} = \frac{\partial E_A}{\partial x} + \frac{\partial E_A}{\partial \alpha}\frac{d\alpha}{dx} = 1.21 \text{ eV for } Zn_{1-x}Mg_xS \text{ with stacking defects } (E_A-$$

location of exciton ground line A, $\alpha = \Delta n/\Delta n_0$- degree of anisotropy,
Δn- birefringence in $Zn_{1-x}Mg_xS$, Δn_0- birefringence in ZnS with wurtzite
structure). The authors thank I. P. Ipatova and A. L. Efros for discussing
the results. Figures 2, references 8: 7 Russian, 1 Western.
[45-2415]

ANABATIC DIFFUSION OF VACANCIES AND INSTABILITY OF IRRADIATED SUBSTANCE

DEVYATKO, Yu. N. and TRONIN, V. N., Moscow Institute of Engineering Physics

[Abstract] There is experimental evidence of unstable behavior of a sub-
stance after long exposure to ionizing radiation, this instability being
manifested in formation of vacancies and precipitation of new phases. A
theoretical interpretation requires a phenomenological approach, inasmuch
as the equations describing the kinetics of glissile point defects do not
admit unstable solutions for the defect concentration unless the mechanism
of anabatic diffusion of vacancies against the substitutional impurity
gradient is specifically added to the mechanism of anabatic impurity diffu-
sion. Only two of the complete system of these kinetic equations are needed,
namely the equations for the rate of change of vacancy concentration and
for the rate of change of complex (substitutional impurity) concentration
respectively. These equations are solved, assuming the existence of
homogeneous and quasi-steady solutions for the concentration of point defects
$n_1^{(0)}$ ($1 = V,I,p,m$) (V- vacancies, I- interstitial atoms of host substance,
p- interstitial atoms of impurity, m- substitutional atoms of impurity).
Assuming that deviations from the quasi-steady solutions are small, the
solution to these equations is sought in a form corresponding to the variation
of vacancy concentration and admitting linear analysis. Such a solution
indicates two possible modes of instability in the given model, namely rise
of local vacancy concentration with formation of vacancy pores or rise of
local complex concentration. The structure of these instabilities can be
examined more thoroughly when the constraint of small deviations from the
quasi-steady solutions is removed. The authors thank I. S. Shapiro for
valuable comments. References 3: 2 Russian, 1 Western.
[43-2415]

ANOMALOUSLY NARROW PEAK OF PERMITTIVITY NEAR DIFFUSE PHASE TRANSITION IN $Cd_2Nb_2O_7$

SMOLENSKIY, G. A., SALAYEV, F. M., KAMZINA, L. S., KRAYNIK, N. N. and
DOROGOVTSEV, S. N., Physico-Technical Institute imeni A. F. Ioffe, USSR
Academy of Sciences

[Abstract] The permittivity and loss tangent of cadmium pyroniobate were
measured with high precision over the 193-213 K temperature range, while
its single crystals with either [111] or [001] orientation were first
cooled and then heated over this range at a rate of 0.05 K/min. The
measurements were made with an E4-7 Q-meter at an electric field intensity
of 200 V/m and at two frequencies: 50 and 400 kHz. The anomalous narrow

permittivity peak did not shift significantly with change of frequency, but an ~ 0.6 K hysteresis of the temperature dependence was detected indicating a phase transition of the first kind near a phase transition of the second kind. The anomalous peak shifted to an ~ 1.5 K higher temperature after specimens had been heated at 700-800 K and returned to their original temperature 5-10 days later. Noteworthy is a change in the domain structure occurring within the 201-205 K interval, characterized by diffusion of the boundaries with apparent breakup into subdomains. The narrow permittivity peak at 201 K can, accordingly, can be interpreted as a consequence of transition from a phase with a diffuse fine-domain structure stabilized by defects to a phase with a ferroelectric domain structure. The authors thank Ye. S. Sher for growing the single crystals of cadmium pyroniobate and V. A. Isupov for helpful discussions. Figures 2, references 6: 5 Russian, 1 Western.
[43-2415]

LONG-WAVE LIGHT-EMITTING DIODES MADE OF $InAs_{1-x-y}Sb_xP_y$ SOLID SOLUTIONS AND OPERATING WITHOUT COOLING

YESINA, N. P., ZOTOVA, N. V., MATVEYEV, B. A., STUS', N. M., TALALAKIN, G. N. and ABISHEV, T. D., Physico-Technical Institute imeni A. F. Ioffe, USSR Academy of Sciences, Leningrad

[Abstract] Solid solutions of the InAs-InSb system are excellent materials for light-emitting diodes used in semiconductor optoelectronics and in gas analyzers. However, the Auger recombination coefficient increases with increasing antimony content and is maximum in the $InAs_{0.7}Sb_{0.3}$ p-n structure most suitable as radiation source. This drawback can be overcome by the use of quaternary solid solutions $InAs_{1-x-y}Sb_xP_y$, namely by adding phosphorus so that the spin-orbital splitting energy Δ will decrease faster than the energy gap E_g will increase and thus resonance between them will be avoided. Specimens of such light-emitting diodes for use in gas analyzers at 300 K were produced experimentally by epitaxy from the liquid phase, p-n films deposited on n-InAs substrates with n = $(1-3) \cdot 10^{18}$ cm^{-3} and the p-region formed by alloying the solution-melt with zinc or manganese. The phosphorus content was varied over the $0.05 \leq y \leq 0.13$ range and the antimony content was held at the $x \sim 0.08$ level. The mismatch between lattice periods did not exceed ± 0.0071 Å and the dislocation density in the best specimens reached $(5-8) \cdot 10^4$ cm^{-2}. The capacitance of these diodes at zero bias voltage was $5 \cdot 10^5$ pF/cm^2. Their current-voltage characteristics and luminescence spectra were measured at 77 and 300 K, with the maximum electric field intensity $5 \cdot 10^3$ V/cm at zero bias. The results indicate a high ratio of "recombination-generation" current component in the space-charge region to "diffusion" current component in

both n- and p- regions at 77 K, also a forbidden band which becomes much
narrower with rising temperature. The luminescence spectra of these
diodes cover the 3-5 μm infrared range, coinciding with the absorption range
of many gases. A radiation power of 200 μW at 2% efficiency is attainable
with a constant d.c. excitation of 15 A/cm^2, a radiation power of 2-5 mW is
attainable with excitation by current pulses of 1000 A/cm^2 and 20 μs duration
at a repetition rate of 20 Hz. Figures 2, references 6: 5 Russian, 1 Western.
[49-2415]

CHANGE IN REFLECTIVITY OF ZINC UPON LASER HEATING OF NANOSECOND DURATION

ZHIDKOV, V. V., IVLEV, G. D., MALEVICH, V. L. and MORGUN, Yu. F.,
Institute of Electronics, BSSR Academy of Sciences, Minsk

[Abstract] The anomalous absorption characteristics of zinc in the red and
near infrared range of the spectrum are, along with changes in its reflectivity
during heating by nanosecond laser pulses, an important factor in the pro-
cess of laser annealing of "Zn film on GaAs substrate" structures during
formation of p-n junctions. An experimental study of the reflectivity of
zinc under such conditions was made using wafers of extra-pure zinc with
mechanically polished mirror surfaces. These specimens were irradiated with
annealing radiation from a monopulse ruby laser and with probing radiation,
the latter consisting of fundamental-mode λ_{prob} = 1.06 μm and second-
harmonic λ''_{prob} = 0.53 μm radiation from a free-emission quasi-continuous
neodymium laser polarized in the incidence plane and impinging at an in-
cidence angle of 30°. The specularly reflected radiation was recorded by
ELU-FTI photomultiplier-photoreceivers and on an S1-7 two-beam oscillo-
graph. A microstructural examination revealed point defects in the form
of 10-20 μm microcavities due to vaporization, perdominantly around
mechanical defects constituting regions of higher absorptivity. The re-
flection coefficient for 1.06 μm waves was found to have changed mostly
under a laser monopulse of 1-4 J/cm^2 energy, namely to have increased by a
factor of 1.5 and to remain so high for a period of time exceeding the
duration of the laser monopulse. A slight irreversible decrease of the
reflection coefficient for 0.53 μm waves and no change in the reflection
coefficient for either wavelength under monopulses of W $\leq$ 0.5 J/cm^2 energy
were observed. The experimental results are correlated with theoretical
results based on the equation of heat conduction with a surface source,
describing the heating and the melting of zinc in the one-dimensional
approximation. This equation was solved by the finite-difference method
with smoothing of coefficients in the implicit scheme, with a 0.02 μm step
along the space coordinate and a 1 ns step along the time coordinate.
Figures 2, references 9 Russian.
[47-2415]

DISCHARGE-PUMPED HIGH PULSE RATE EXCIMER LASER

[Article by A. Vill, T. Klementi, V. Mikhkel'soo and V. Altukhov]

[Text] UV excimer lasers, especially discharge-pumped high pulse rate
lasers, are distinguished by simplicity of construction, high efficiency,
high peak power and high average power [1-5], thanks to which they are
being utilized increasingly in science and for practical purposes. They
are being used, for example, for pumping dye lasers, purification of
substances in selective laser chemistry, etc.

Our objective was to develop and investigate experimentally a compact
excimer high pulse rate laser with relatively high efficiency and high
pulse energy, and to select optimal parameters for the power system and
laser radiation through model calculation of oscillograms of the discharge
current and circuit voltage.

The electrical circuit of the ELI-2 high pulse rate excimer laser is a
traditional TEA-circuit [6] with the working gas blown transversely between
the electrodes. The Blumline oscillator employs type KVI-3 capacitors,
with a TGI-1-1000/25 thyratron as the switch. It is important to note
that "peaking" capacitors are connected in parallel with the discharge
circuit, making it possible to increase the efficiency by a factor exceeding
1.5 by selecting optimal capacitance values. Pre-ionization is done by
UV illumination by a capacitive discharge through a dielectric (glass in
the present case). The pre-ionizers are placed as close as possible to
the discharge space. The distance between electrodes is about 20 mm,
the electrodes are 600 mm long, and the radius of curvature of both
electrodes is 20 mm. The pre-ionization method employed provides a
uniform capacitive discharge and elevated diffuseness of the basic discharge.
Uniformity of the capacitive discharge prevents erosion of the electrodes,
which is important for long-life periodic pulsed lasers.
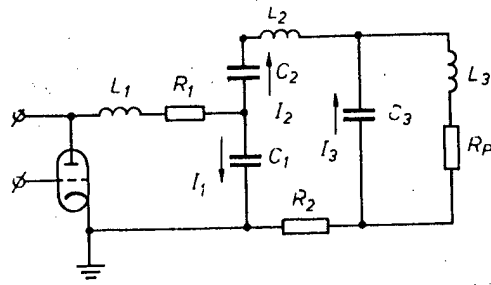
Fig. 1. Equivalent electrical circuit of laser power supply system

The laser is constructed as two modules: a) a radiator with a ballast space and proportional gas replacement and dispensing system, and b) a control unit with power supply. The latter allows the laser to operate at a pulse repetition frequency of up to 100 Hz. The high voltage capacitors are charged by an impulse transformer with storage capacitors connected to the primary winding. The switch is a TChI-100 thyristor. Gas is blown through the laser cuvette by three parallel axial fans which are turned in the working space by means of magnetic clutches. The ballast space comprises 100 liters, and the power supply has efficiency of approximately 70%.

In order to calculate the oscillograms of the current and voltage of the discharge circuit of the laser power system it was necessary to solve a system of Kirchhoff equations, which are conveniently written as follows for our electrical discharge system (Fig. 1):

$$\dot{I}_1 = F/L_1 - q_1/L_1C_1 - R_1(I_1+I_2)/L_1, \tag{1}$$

$$\dot{I}_2 = -F/L_2, \quad F = R_2I_2 - q_1/C_1 + q_2/C_2 - q_3/C_3, \tag{2}$$

$$\dot{I}_3 = F/L_2 - q_3/L_3C_3 - R_p(I_2+I_3)/L_3. \tag{3}$$

The currents I_1, I_2, I_3 and the initial conditions for the charges and currents $I_i(0)$ (i=1,2,3) for a given initial voltage V_0 are defined by the relationships

$$I_1 = \dot{q}_1, \quad I_1(0) = 0, \quad q_1(0) = C_1V_0,$$

$$I_2 = \dot{q}_2, \quad I_2(0) = 0, \quad q_2(0) = C_2V_0,$$

$$I_3 = \dot{q}_3, \quad I_3(0) = 0, \quad q_3(0) = 0.$$

The values of the resistance R_1 and inductances L_1, L_2 and L_3 of the discharge circuit

$$R_1 = 0.1 \text{ Ohms}, \qquad L_1 = 2 \cdot 10^{-7} \text{ H},$$
$$L_2 = 2 \cdot 10^{-9} \text{ H}, \qquad L_3 = 5 \cdot 10^{-9} \text{ H}$$

were selected on the basis of general construction considerations and the proposed average power of a laser (approximately 10 W), and the values of the other parameters C_1, C_2, C_3, R_2 and R_p were selected in accordance with the principle of maximum attainable efficiency and best agreement between calculated discharge oscillograms and experimentally observed oscillograms of voltage across "peaking" capacitance C_3. The resistance of the plasma R_p was approximated by a step with R_p dropping off to 0.5 Ohms at the moment of breakdown of the discharge interval approximately 80 nsec after initiation of switching. The qualitative and quantitative agreement in the behavior of the calculated and measured oscillograms (cf. Fig. 2) indicates the applicability of the approximation we used for $R_p(t)$. In selecting the value of C_3, in addition to the optimal coefficient of transfer of the energy stored in the capacitors to the plasma

$$K = \varepsilon_b/\varepsilon_0, \tag{4}$$

where $\varepsilon_0 = V_0^2$, allowance was made for achieving maximum efficiency, limiting the quantity C_3 from below. The energy contribution to the discharge was taken into account prior to the first zero-crossing of the discharge current $I_p(t) = I_2(t) + I_3(t)$.

Values of $R_2 \leq 0.01$ Ohms, $C_1 = 9 \cdot 10^{-9}$ F, $C_2 = 19 \cdot 10^{-9}$ F, $C_3 = 10 \cdot 10^{-9}$ F were found, which provide maximum output of generation energy with a standard working mixture of HCl:Xe:He (0.2:4:95.8%). By varying the parameters of the power supply, it was possible to select a favorable discharge mode with sufficiently steep voltage rise (approximately 18 kV over 80 nsec) and with a short (approximately 20 nsec) but strong (approximately 25 kA) discharge current pulse (cf. Fig. 2). By using the values found for C_1 and C_2, and the breakdown voltage measured for this mixture $V_0 = 24$ kV, we obtain efficiency of approximately 0.9% for an XeCl laser.

When working with XeF, the halogen donor was NF_3, since the glass textolite insulation of the discharge chamber did not permit fluorine to be used. Lasing was obtained with a mixture of NF_3:Xe:He (1:3:500) at
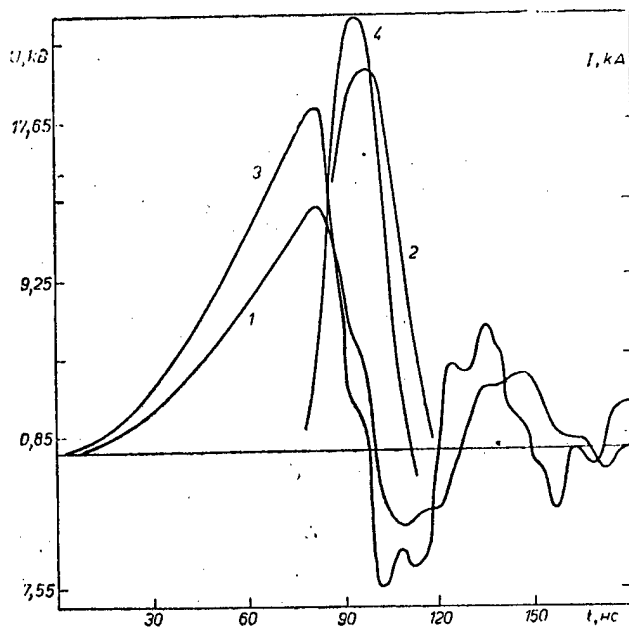
Fig. 2. Time dependency of discharge current (2,4) and voltage (1,3):
curves 1 and 2 for $C_3 = 10^{-18}$ F, curves 3 and 4 for $C_3 = 5 \cdot 10^9$ F.

a pressure of 2.3 atmospheres. The pulse energy at pulse repetition frequencies of up to 100 Hz was 100 mJ, with average power of 10W. Unfortunately, the service life of the mixture containing NF_3 with the purity we were able to achieve (approximately 96%) is fairly short, and with a ballast volume of 100 liters totals approximately $3 \cdot 10^4$ pulses (with the generation energy cut in half (Fig. 3)). In determining the service life, voltage oscillograms were recorded in parallel, for which the appearance remained practically unchanged as the working mixture aged.

9
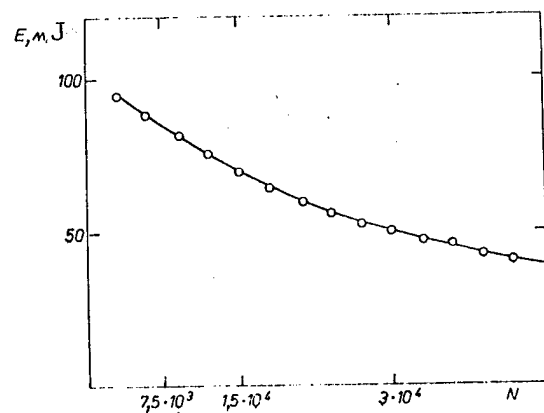
Fig. 3. Pulse lasing energy E as function of number of pulses N
working with XeF
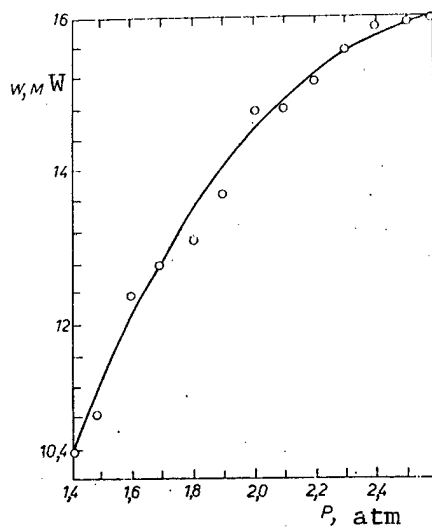
Fig. 4. Pulse power W as function
of pressure P working with XeCl
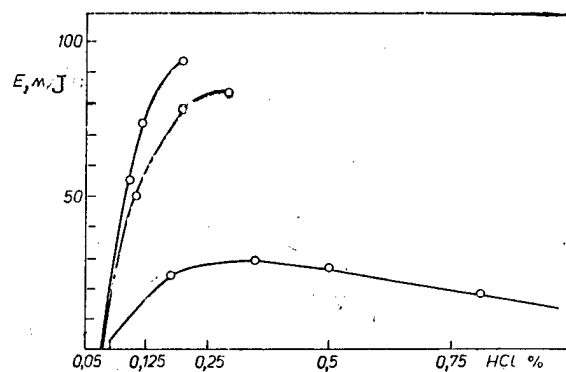
Fig. 5. Pulse radiation energy E as
function of composition of working
mixture HCl:Xe:He

In the case of XeCl for a standard HCl:Xe:He mixture the pulse radiation energy is 75 mJ, with efficiency of approximately 0.9% and pulse repetition frequency of up to 100 Hz. The continuous operation duration with XeCl amounts to 10^6-10^8 pulses, which is significantly longer than for XeF. The shape and duration of the lasing pulse were recorded with the help of an FEK-29 and an S7-13 stroboscopic oscillograph. The lasing pulse duration of the XeCl laser is approximately 15 nsec. When the pressure drops from 2.6 to 1.4 atm the XeCl pulse power drops from 16 to 10.4 MW (cf. Fig. 4).

In analyzing the relationship between output energy and composition of working gas a scheme for proportional dispensing of the components and spraying them into the working chamber was employed. This made it possible to regulate the composition of the components to within 0.005%. Figure 5 shows the output energy as a function of HCl content for various doses of Xe (0.6, 2.3, 3.5%). For small doses of HCl the nature of the voltage oscillograms is practically independent of the composition of the working mixture; however, when the content is increased 1% the shape of the voltage pulse changes sharply, and the discharge becomes highly unstable with a large number of streamers.

Conclusions

The ELI-2 discharge-pumped high pulse rate excimer laser was developed. System efficiency of about 1% was achieved by optimal selection of the parameters of the power system. With pulse repetition frequencies below 100 Hz, pulse radiation energy of 75 mJ was obtained for XeCl, and 100 mJ for XeF.

During the development it was also possible to solve a number of engineering and technical problems associated with improving the operating reliability and convenience of maintenance of the laser.

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TUNABLE FAR IR ZONE HETEROLASER WITH WAVELENGTH TO 46.2 μm

KURBATOV, L. N., BRITOV, A. D., KARAVAYEV, S. M., SIVACHENKO, S. D.,
MAKSIMOVSKIY, S. N., OVCHINNIKOV, I. I., RZAYEV, M. M. and STARIK, P. M.

[Abstract] A report is presented on a significant expansion in the spectral
bandwidth of laser diodes into the far IR region. Optical long wave laser
radiation at 46.2 μm has been achieved in heterolasers based on a four-
component PbSnTeSe solid solution. $(PbSe)_{0.80}(SnTe)_{0.20}$ Single crystals
were grown from the vapor phase with an initial hole concentration of about
10^{19} cm^{-1}. Subsequent annealing in metal vapors reversed the conductivity
type and reduced the carrier concentration to 10^{17}-10^{18} cm^{-3}. Laser hetero-
structures were manufactured by photostimulated gas epitaxy. A charge
of $PbTe_{0.68}Se_{0.32}$ was used to apply the wideband epitaxial p-type layer.
p- and n-electrodes of the heterostructures were obtained by chemical
precipitation of gold. The emission spectra of the laser diode are illustrated.
One characteristic feature of the laser diodes studied is comparatively
slight (factor of three) reduction in threshold current density as tempera-
ture drops from 78 to 6 K. The authors do not feel that the wavelength
obtained is by any means the limit for laser diodes of this type. Figures 2,
references 4: 3 Russian, 1 Western.
[52-6508]

COHERENT EFFECTS IN GENERATION AND AMPLIFICATION OF ULTRASONIC PULSES IN Nd:YAG AND RUBY AT LOW TEMPERATURES

VARNAVSKIY, O. P., KIRKIN, A. N., LEONTOVICH, A. M., MIRZOYAN, R. G.,
MOZHAROVSKIY, A. M. and SATAYEV, I. R., Physics Institute
imeni P. N. Lebedev, USSR Academy of Sciences

[Abstract] The coherent interactions of light pulses with resonant media
have been studied for absorbing media. This article presents studies in

gases in the nanosecond length range. The results agree in general terms
with the results of the much more numerous theoretical works dedicated to
this problem. The experimental results presented in this work deal with
the generation and amplification of ultrashort pulses in Nd:YAG and ruby
at low temperatures. Amplification was studied at the junction between
R_1-Y_1 components of the multiplex $^4F_{3/2}$-$^4I_{11/2}$ using rods measuring
5 x 60 and 8 x 80 mm pumped with flash lamps cooled to about 100 K by
nitrogen vapor. Estimates of the inverse of heterogeneous width from
spectroscopic data yield values of 20 psec and 150 psec, respectively.
Input pulses were supplied by a self-mode-locked Nd:YAG laser. Pulse
length was about 80 psec, energy about 1 mJ, beam diameter 2 mm. Coherent
effects in generation and amplification of picosecond pulses in condensed
media have not been previously described in the available literature.
Figures 2, references 12: 9 Russian, 3 Western.
[51-6508]

LITHIUM NIOBATE CRYSTAL LASER WITH FREQUENCY DEGENERATE PUMPING

ODULOV, S. G. and SOSKIN, M. S., Institute of Physics, Ukrainian SSR
Academy of Sciences

[Abstract] Lasing by interaction of two coherent light beams in a
medium with nonlocal response is performed in lithium niobate crystals
doped with iron with excitation by continuous He-Cd laser radiation. The
diffusion nonlinearity observed previously in $BaTiO_3$ crystals was used,
nonlocal nonlinearity specific for activated crystals, related to spatially
oscillating photogalvanic currents. Lasing was obtained in plane parallel
specimens of reduced lithium niobate crystals with 0.03 wt.% iron, 0.4 cm
thick. In all cases a sharp rise in light induced pumping radiation
scattering was first observed, an analog of the superluminescence in ordinary
laser systems. A brighter spot was then developed, corresponding to the
lasing beam oriented perpendicular to the ends of the specimen. The in-
tensity of radiation scattered at other angles decreased greatly. The
angular divergence of the generated beam in most cases was about 5 degrees,
but it was structured and frequently contained a core with divergence close
to that of the pumping beam, about 30 minutes. Lasers based on the
principle of dynamic holography open new prospects for the correction of
the wave fronts of laser beams in real time and effective generation of
beams with assigned space-angle structure. Figures 2, references 17:
8 Russian, 9 Western.
[51-6508]

ONE MECHANISM OF DEVELOPMENT OF NONLINEAR CURRENT-POWER CHARACTERISTIC
SPECIFICS IN FLAT HETEROLASERS

SURIS, R. A. and SHTOFICH, S. V.

[Abstract] A study is made of a simple model of a flat heterolaser in
which the current I is homogeneously pumped in an undoped active layer
in a band of width α_1 beneath a junction created by a concentration of
free electrons. The remainder of the active layer is not pumped. The
radiation of the laser propagates both through the pumped area beneath
the contact and the unpumped areas on either side. Equations are derived
which explain the increase in slope of the current-power characteristic
with an increase in laser mirror reflection coefficient. The increase in
laser radiation power and related deformation of the laser waveguide may
result in the development of new transverse modes and generation channels.
References 8: 2 Russian, 6 Western.
[50-6508]

CURRENT-VOLTAGE CHARACTERISTICS OF STRIP HETEROLASERS

SURIS, R. A. and SHTOFICH, S. V.

[Abstract] Attention is drawn to one mechanism of development of specifics
in characteristic U(I) in strip lasers. Absorption of radiation in un-
pumped areas of the active layer leads to nonlinear specifics of P(I).
The influence of this mechanism on characteristic U(I) is studied. A
simple equivalent circuit of a strip laser is illustrated and studied. The
laser operates without pecularities at the lasing threshold only where
$\theta < \theta_1$. The development of the specifics of cha acteristic U(I) after
training of the laser can be explained by the decrease in doping of the
active layer due to diffusion of impurities from emitters or self-
compensation. U(I) curves at the threshold of excitation of each trans-
verse mode may have the same specifics as are possible at the threshold of
the primary mode. Figure 1, references 6: 3 Russian, 3 Western.
[50-6508]

INJECTION BRAGG HETEROLASER WITH HIGH TEMPERATURE STABILITY OF RADIATION
WAVELENGTH

GUREVICH, S. A., NESTEROV, S. I., PORTNOY,,Ye. L., SKOPINA, V. I. and
TIMOFEYEV, F. N., Institute of Physics and Technology imeni A. F. Ioffe,
USSR Academy of Sciences, Leningrad

[Abstract] The first report is presented on the creation of an injection
heterolaser with distributed Bragg mirror based on a Ta_2O_5 dielectric
waveguide. Significantly weaker variation in position of lasing line on
temperature is observed in this laser than in ordinary distributed Bragg
mirror lasers based on semiconductor waveguides. The laser was made of a
Ga(Al)As heterostructure in which the waveguide consisted of three layers
with the narrowest GaAs layer in the center, providing for excitation of the
zero waveguide mode. The spectral position of the distributed reflection
band in this laser depends on temperature as the effective index of re-
fraction of the dielectric waveguide depends on the temperature. In the
area of transparency of the waveguide material this dependence may be quite
weak, explaining the high temperature stability of lasing lines.
Figures 3, references 7: 3 Russian, 4 Western.
[50-6508]

FEASIBILITY OF FORMING SHORT LASER PULSES IN COHERENT-EMISSION MODE

NAZARKIN, A. V., POLUEKTOV, I. A. and SOBEL'MAN, I. I., Institute of
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[Abstract] It is demonstrated theoretically that the energy of an $n\pi$-pulse
passing through a resonant absorbing medium can be efficiently transferred
to a pulse at the frequency of a neighboring transition and with a much
shorter duration. A medium of 3-level atoms is considered, for specificity,
and in it propagating a steady 2π-pulse at frequency $\omega_0 \approx \omega_{31}$ and of duration
τ_0 followed by a weak signal pulse at frequency $\omega_s \approx \omega_{32}$ and of duration
$\tau_s < \tau_0$. The group velocity v_0 of the pump pulse is much lower than the
phase velocity of light c in the medium, but the group velocity of the
signal pulse is $v_s \approx c$. A solution of the system of corresponding
self-consistent field equations yields the condition for signal amplification
through energy transfer from the pump pulse: $(\omega_s/\omega_0)(\mu_{23}/\mu_{13})^2 > \tau_0/\tau_{s0}$
with corresponding pair of transitions $1 \rightarrow 3$, $3 \rightarrow 2$ $(\mu_{23}/\mu_{13} >> 1)$ $(\mu_{13}, \mu_{23}$-
dipole moments of transitions). The quantity

$\theta_s = (\mu_{23}/\hbar) \int_{\infty}^{\infty} |E_s| dt$ (E_s- complex pulse amplitude) can be equal to π, such

a π-pulse being stable in a coherently amplifying medium. Numerical calculations confirm this, also that the energy transfer is negligible when $\theta_s \ll 1$. When $1 \sim \theta_s < \pi$, the energy transfer is appreciable and the duration of the signal pulse remains almost constant $\tau_s \sim \tau_{s0}$. Figures 2, references 3 Russian.
[44-2415]

LASER MODE LOCKING BY TRAVELING-ACOUSTIC-WAVE MODULATOR

KRAVTSOV, N. V., MAGDICH, L. N., SHELAYEV, A. N. and SHNITSER, P. I.

[Abstract] The feasibility of forced locking of laser modes on a traveling acoustic wave, by means of a modulator with diffractional optoacoustic feedback, has been established in an experiment with a YAG:Nd^{3+} ring laser. The optoacoustic modulator consisted of a 36°Y-cut LiNbO$_3$ piezoradiator, an acoustic waveguide wedge made of fused quartz with Brewster faces, and a sound absorber. This modulator operated in the Bragg diffraction mode. Radiation diffracted by the modulator could be fed back to it and to the main laser resonator in three ways: 1) by means of one reversing mirror; 2) by means of two mirrors forming a linear resonator with a diaphragm between them; 3) by means of three mirrors forming another ring resonator. The piezoradiator was excited by a microwave oscillator through an amplifier. A condition for stable mode locking is space-time overlap of ultrashort light pulses propagating in the laser ring resonator and ultrashort light pulses injected by the feedback, which can be achieved by matching the optical lengths of feedback branch and laser perimeter. No forced mode locking is possible without feedback, but has been achieved on a standing acoustic wave in an earlier experiment. Figure 1, references 3 Russian.
[49-2415]

MECHANISMS OF INTERACTION OF NANOSECOND LASER RADIATION AND METALS

SUD'YENKOV, Yu. V., FILIPPOV, N. M., VOROB'YEV, B. F. and NEDBAY, A. I.

[Abstract] Interaction of radiation from a nanosecond laser with metals was studied by the acoustic method. Copper and aluminum specimens were irradiated over a polished surface area 0.5 cm in diameter with pulses at the $\lambda = 0.69$ µm wavelength of $3 \cdot 10^{-8}$ s duration. The power density of

incident radiation flux, varied over the $1 \cdot 10^6 - 3 \cdot 10^8$ W/cm^2 range through regulation of the pumping power in two amplifier stages, was measured with a calorimeter. The acoustic signals emitted by the target surface upon impact of radiation pulses were recorded by an oscillograph after passing through a piezoelecgric transducer operating in the short-circuit mode. Also recorded were signals from an FEK-09 photodiode measuring the pulses of light specularly reflected by the metal surface and signals from an FEU-87 photomultiplier indicating the time of flare-up. The acoustic signals from an FEU-87 photomultiplier indicating the time of flare-up. The acoustic signals were characterized by compression (positive) and rarefaction (negative) jumps in time, their magnitude and time of occurrence depending on the rarefaction (negative) jumps in time, their magnitude and time of occurrence depending on the radiation flux density. The intensity of specular reflection was also found to depend on the radiation flux density. Evidently phase transitions, melting and subsequent evaporation with attendant strong absorption of radiation followed by optical break-down (at 90 MW/cm^2 for copper) play a significant role in this process. At radiation flux densities above the breakdown level the acoustic signal ceases to increase and becomes unipolar compressive and specular reflection of light weakens, the flame acting as a shield over the metal surface. This situation prevails till the radiation flux density has reached another level at which the "piston-flame" expands generating a strong shock wave and a second peak in the acoustic signal. Figures 3, references 9 Russian. [49-2415]

COHERENCE OF RADIATION FROM SEMICONDUCTOR LASER WITH EXTERNAL
REFLECTING ELEMENT

SURIS, R. A. and TAGER, A. A., Institute of Radio Engineering and
Electronics, USSR Academy of Sciences, Moscow

[Abstract] It has been established experimentally that the coherence path of radiation from a semiconductor laser can be lengthened by means of an external selective mirror. The narrowing of the emission line with the mirror at a distance from the isolated laser shorter then the coherence path was already calculated. Here the narrowing of the emission line is calculated for the case of the mirror at a distance longer than the coherence path. Calculations are based on the "short" equation describing the field in the active zone of a single-mode semiconductor laser in the approximation of very weak coupling with a "mirror" (e.g. a dust mote). The selectivity of the mirror is assumed to be negligible within a frequency range of the order of several intermode separations in the external resonator and no windows are assumed to form in the amplification line with resulting multimode emission. The equation is solved by the Langevin method for the time coherence function, taking only phase fluctuations into account. The conditions are established under which the mirror becomes effective and the

coherence function approaches its asymptotic limit without oscillations. The emission spectrum as well as its evolution with increasing pump energy and increasing length of the coherence path, from multimode to single-mode, are analyzed on this basis with the aid of Fourier transformation of the coherence function. Figures 2, references 3 Western.
[48-2415]

FAST-TUNABLE LASER BASED ON OPTOACOUSTIC FILTER

ABRAMOV, A. Yu., MAZUR, M. M. and PUSTOVOYT, V. I., All-Union Scientific Research Institute of Physicotechnical and Radiotechnical Measurements

[Abstract] A tunable dye laser is considered with which a collinear optoacoustic filter energized by controllable microwave power and placed inside the resonator cavity serves as tuning element (O. J. Taylor, S. E. Harris, S. T. K. Nieh, T. W. Hansch APPLIED PHYSICS LETTERS Vol 19, 1971). The optical system includes, in addition to the filter, an orthogonally polarizing Rochon prism and an end mirror on each side of the "active medium - potoacoustic filter" system. Optical and acoustic waves interact parametrically in the filter and some of the laser radiation, reflected and polarized, is fed back to the active medium. The necessary condition for emission is established in terms of optical gain in the active medium and efficiency of parametric interaction in the filter, whereupon the performance characteristics of such a laser, particularly the diffraction efficiency, are calculated. An experiment was performed with rhodamine 6G as active medium and a quartz crystal as optoacoustic filter (tuning range 0.4-0.8 µm, bandwidth 3.0-5.0 Å, power efficiency 0.7 maximum and controllable through regulation of the microwave input over the 1-20 W range). The active medium was pumped with radiation from an INP2-5/75 flash lamp. The emission spectrum was found to be notched, an indication of high sensitivity, owing to the intrinsic resonance characteristics and 400 kHz frequency separations of the filter. The authors thank V. M. Zakharov and Yu. K. Kalinnikov for assistance in tuning the optoacoustic filter. Figures 2, references 5: 2 Russian, 3 Western.
[47-2415]

CO_2-LASER WITH RADIOISOTOPE PREIONIZATION

LAVRENTYUK, V. Ye., PODMOSHENSKIY, I. V. and ROGOVTSEV, P. N.

[Abstract] A pulsed CO_2-laser has been built and tested, with preionization of the active medium by α-particles from plutonium sources. The energy of

α-particles here exceeds 5 MeV, sufficient for them to penetrate 10 cm into a gaseous medium such as CO_2 under atmospheric pressure. The dose of γ-radiation is four orders of magnitude below the tolerance level so that no protective shielding is required. The laser operates with transverse excitation from complete discharge of a noninductive capacitor through a preionized 16 mm gap. Solid aluminum electrodes and flat capsules containing radioactive sources with an activity of approximately 0.08 mCi/cm^2 are placed inside a chamber with dielectric walls which, after evacuation, has been filled with a prepared CO_2:N_2:He gas mixture. The path-of-flight of α-particles is always longer than the distance between their sources. With self-sustained volume always longer than the distance between their sources. With self-sustained volume discharge it is possible to generate current pulses of 30 A/cm^2 (1.5 μs duration) to 120 A/cm^2 (0.35 μs duration), depending on the electric field intensity. A pumping energy of 200-250 $J/(dm^3 \cdot atm)$ is attainable and an overall laser efficiency of 2-3.5% is attainable, the latter depending on the electric field intensity as well as on the gas composition and pressure. Figures 27, references 4: 3 Russian, 1 Western.
[47-2415]

NUCLEAR PHYSICS

EMISSION OF SECOND HARMONIC AND MEASUREMENT OF COMPRESSION RATE IN CASE
OF SHELL TARGETS WITH LARGE ASPECT RATIOS

BASOV, N. G., KALASHNIKOV, M. P., MIKHAYLOV, Yu. A., OSIPOV, M. V.,
RUPASOV, A. A., SKLIZKOV, G. V., FEDOTOV, S. I, and SHIKANOV, A. S.,
Institute of Physics imeni P. N. Lebedev, USSR Academy of Sciences

[Abstract] Compression of glass and polystyrene shells with large aspect
ratios $A_s = R_0/\Delta_0 > 100$ (R_0 – radius, Δ_0 – thickness) in the "Del'fin-1"
laser apparatus was studied experimentally by methods used for diagnosis
of plasma dynamics near the critical density ($n_{cr} \simeq 10^{21}$ cm^{-3}). A radiation
flux density $q_0 \lesssim 5 \cdot 10^{13}$ W/cm^2 in pulses of 2.3 ns duration at the target
surface was produced by six compounding laser beams with a total energy
of 1 kJ, approximately half the energy being absorbed. The spectrum of
the heating laser radiation was 100 Å wide at the 50%-intensity level,
with the peak at the $\lambda_0 = 10{,}598$ Å wavelength. The spectrum of the second
harmonic generated in the plasma was 50 Å wide, with Doppler shift of the
peak 5299 Å by 5-12 Å toward longer waves. Only $10^{-6} - 10^{-5}$% of the laser
energy was transferred to the second harmonic. The maximum compression
rate according to this Doppler shift of the second harmonic was $2.75 \cdot 10^7$ cm/s.
It was $3 \cdot 10^7$ cm/s according to data obtained by scanning the x-ray images
of the plasma in time and by plotting the trajectory of inward shell
movement, the mean compression rate being here $1.4 \cdot 10^7$ cm/s. The results
do not quite agree with those based on scaling the results of measurements
made in the "Kal'mar" laser apparatus on such shells with small aspect
ratios $A_s < 30$, because of the different compression dynamics in each case.
Figures 3, references 6 Russian.
[45-2415]

X-RAY IMAGES AND COLLAPSE TIME OF GAS-FILLED GLASS MICROSPHERES WITH
ASPECT RATIO OF 100-200 AFTER ENERGY INPUT OF 0.2 J/ng

VOLENKO, V. V., IVANOV, A. F., MYALITSIN, L. A., OSADCHUK, L. A. and
SAUKOV, A. I.

[Abstract] Increasing the specific laser energy input to a target above
0.1 J/ng is necessary for increasing the neutron yield, but is feasible
only with targets having a very small mass and a large aspect ratio
R/ΔR (R- radius of sphere). Using thin shells as targets is problematic,
inasmuch as increasing their aspect ratio results in appreciable short-wave
symmetry distortions and possibly loss of stability under adiabatic com-
pression. A series of experiments was performed in the "Sokol" apparatus,
using targets with a mass of 40-60 ng and aspect ratios from 100 to 200.
The nonuniformity of target illuminance was $\pm$10%, that of laser energy
absorption only $\pm$5%. An energy input of 0.2 J/ng was reached, at which
the target collapse time ranged from 0.9 to 1.2 ns. All integral x-ray
image densitograms revealed a central glow of targets, but only at the
1.3 keV quantum energy level with the aspect ratio within the 100-170 range
and also at the 2.6 keV quantum energy level with R/ΔR $\gtrsim$ 170, also at the
3.5 keV quantum energy level in the case of a symmetric target. The results
indicate the feasibility of obtaining necessary compression ratios with such
targets and of finding optimum targets for laser-driven fusion within a wide
range of aspect ratios. Figures 4, references 9: 4 Russian, 5 Western.
[44-2415]

BREMSSTRAHLUNG FROM ELECTRONS IN ATOMIC POTENTIAL: CLASSICITY OF SPECTRUM
AND SIMILARITY LAWS

KOGAN, V. I. and KUKUSHKIN, A. B., Institute of Atomic Energy
imeni I. V. Kurchatov

[Abstract] The theory of bremsstrahlung from electrons in the approximation
of a static atom potential is applied to the problem of determining the
integral (with respect to the photon emission angle) bremsstrahlung spectrum.
A classical description has been found to be approachable for keV energy
levels on the basis of the Thomas-Fermi model of a many-electron atom, with
$1/\varepsilon \sim Z^{4/3}E$ (Z- atomic number, E- electron energy in atomic units) as the
quasi-classicity parameter. Tedious numerical computations for a complete
classical description are avoided by considering the two extremes, both

readily admitting analytical treatment. At the zero-frequency "transport" limit the Gaunt factor in terms of cross section for elastic scattering can be calculated analytically when $\varepsilon \leq 10^{-2}$ or $\varepsilon \gg 1$. At the high-frequency limit a unique relation between bremsstrahlung frequency and angular velocity of the electron emitting it when located closest to the center of the field allows using a "rotational" approximation. Similarity laws are established on this basis for comparative evaluation of quantum and classical parameters, also for evaluating the short-wave edge ($\omega_{max} = E/\hbar$) of the bremsstrahlung spectrum. The authors thank V. I. Gervids for valuable collaboration, A. G. Zhidkov for mentioning an important reference (M. Semaan and C. Quarles in Phys. Rev. Vol. 26A, 1982) and V. S. Lisitsa for discussing the results. Figures 3, references 8: 5 Russian, 3 Western.
[43-2415]

USE OF HIGH-GRADE CRYSTALS FOR X-RAY DIAGNOSTICS IN STUDY OF LASER-DRIVEN FUSION

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[Abstract] X-radioscopy is an effective method of diagnosing the targets and the plasma of target material during experiments with laser-driven fusion, crystals being required for the spectrograph which will not only ensure a high spectral and space resolution but also cover a wide range of wavelengths. A spectrograph with plane crystal is preferable to a focusing spectrograph or to one with convex crystal, because its luminosity at a fixed source-crystal distance does not depend on wavelength, frequency range, and crystal geometry: $d\gamma/d\theta = \text{const} = 1$ (γ - divergence angle, θ - Bragg angle), also because its resolution is the maximum attainable on account of zero surface curvature. Plane crystals are easiest to produce without lattice distortion from any material, quartz and silicon being the most suitable materials for this application. The spectroscopic character- istics of quartz crystals with revlection by the (1010)-plane and of silicon disks (single crystals) with flat surfaces in (111)-plane have been measured for quality control and spectrograph optimization in terms of theoretical radiation intensity as well as spectral and space resolution. The per- formance of quartz and silicon X-ray spectrographs was comparatively evaluated in experiments with aluminum, silicon, sulfur and phosphorus targets. The space resolution of the quartz crystal was checked against the spectrum of He-like Al-XII aluminum ions, that of the silicon crystal was checked against the spectrum of H-like Si-XIV silicon ions and He-like S-XV sulfur ions. The feasibility of forming a two-dimensional target image in the light at the wavelength of its intrinsic emission line with a high space

resolution was established, with a phosphorus target, by producing a photograph of two plasma flares separated by means of a laser-beam splitting optical wedge. The reflection characteristics of real quartz and silicon crystals were measured, and the results correlated with the dynamic theory of X-ray interference for scattering by an ideal single crystal under three possible conditions: 1) primary extinction strong and absorption weak; 2) extinction and absorption approximately equal; 3) extinction weak and absorption strong. With these data available, a method of measurement has been developed for the absolute intensity of line-spectrum radiation from a plasma. The theory of this method, based on photon count, has been applied to experiments with plasma heating by laser radiation with flux density of the order of 10^{14} W/cm^2. Also an X-ray schlieren method has been developed, for inspection of targets used in experiments with laser-driven fusion. This method, based on the geometrical-optics approximation with physical-optics correction for diffraction and chromatic aberration, can be optimized as a tradeoff either between a large shift of the Bragg angle with simple interpretation of topograms and a long exposure time or between a small shift of the Bragg angle with high intensity in the plane of recording and a difficult readout requiring higher precision of intensity measurement. The first alternative was explored as possibly the preferable one. Experimental results obtained by this version of the X-ray schlieren method with the optimum configuration were compared with and calibrated against measurements made with a scanning electron microscope, by microradiography, and by two methods of optical interferometry. While ensuring a comparable accuracy (± 0.15 μm), the X-ray schlieren method offers two advantages over optical interferometry: it does not require that the target material be transparent and the shell thickness can be measured directly on account of almost rectilinear propagation of X-rays. The accuracy of this method can be further improved by reduction of the distance from target to photographic film, a higher magnification, and microphotothermal treatment with calculation of intensity profiles. An accuracy within ± 0.05–0.1 μm appears to be feasible. The authors thank Academician N. G. Basov for his undiminishing attention and professor D. Unangst for helpful discussions, also A. Christoff and Dr. U. Alter of the "Karl Zeiss" Works in Jena for assistance in preparing crystal specimens, professor A. Meisel and Dr. H. Sommer of the Karl Marx University in Leipzig for offering the facilities of their laboratory for certain measurements, and E. Knoll, M. Rabold, A. A. Galichem and V. N. Puzyrev for assistance. Figures 32, tables 2, references 59: 28 Russian, 31 Western.
[42-2415]

24

DYNAMICS OF PLASMA CORONA ON SPHERICAL TARGETS UNDER LASER RADIATION

ZAKHARENKOV, Yu. A., ZOREV, N..N., RUPASOV, A. A., SKLIZKOV, G. V. and
SHIKANOV, A. S.

[Abstract] Experiments were performed for a study of interaction of laser
radiation and plasma corona, specifically the effect of laser radiation on
the hydrodynamics of plasma dissipation and corona formation during the
first two stages: evaporation and compression. Solid microglobules of
glass (SiO_2) and tin as well as spherical microshells of silica, alumina,
and polystyrene (C_8H_8), 70-25 μm in diameter, were used for irradiation
with laser pulses of up to 200 J energy and 2 ns duration in the "Kal'mar"
equipment with a special high-speed optical diagnostic system. The latter
included a ruby laser or a neodymium laser with a frequency doubling KDP
crystal, an optical delay line, a Jamin interferometer, an objective lens,
a semitransparent mirror, a displacement interferometer, another lens and
a set of mirrors, an interference-type light filter, a discharger with
laser ignition, a photoelectric recording device, a focusing-on-target lens,
beam splitters, and a multiframe interference-type photographic camera.
This instrumentation tracked the evolution of the density profile and the
dynamics of density perturbations in the corona so that the hydrodynamic
parameters and the effect of perturbations on corona dissipation could be
determined. The critical-density region and its kinetics were recorded
and measured photographically with both space and time resolution, its
velocity being determined from the second-harmonic radiation and its electron
temperature being determined from the 3/2-harmonic radiation. The energy
spectrum of plasma ions, namely their charge and velocity distributions,
was measured with special equipment including ion collectors with negatively
biased grids in grounded housings, an electrostatic ion analyzer, and a
secondary-emission multiplier. Fast ions moving in a jet through spherically
adiabatically expanding plasma were recorded by both interferometry and
schlieren photography. The results of these experiments are now evaluated
and analyzed from the standpoint of hydrodynamic theory of laser plamsa,
including various models of density profile deformation and charged-
particle acceleration such as resonant acceleration of ions near the
critical-density region. Figures 35, table 1, references 119: 58 Russian,
61 Western.
[42-2415]

HEATING AND COMPRESSION OF SPHERICAL TARGETS BY LASER RADIATION

VASIN, B. L., YEROKHIN, A. A., ZOREV, N. N., KOLOGRIVOV, A. A.,
RUPASOV, A. A., SKLIZKOV, G. V. and SHIKANOV, A. S.

[Abstract] Two important processes in laser-driven fusion are radiation
absorption by the target through various mechanisms and plasma compression,
the latter limited by hydrodynamic instabilities. Prototype laser power
equipment for experimental study of these processes was built in 1971,
furnished with a series-parallel amplification system, and finally modified
in 1974 into the "Kal-mar" 9-channel facility. The latter was subsequently
improved in 1979 so that it can now operate with laser pulses of 250 J
energy and brightness exceeding 10^{17} W/(cm^2·sr), the spectral composition
being controllable. It consists of a master laser, a pulse shaper, a
module of preamplifier cascades, a module of power amplifier cascades, a
beam focusing and aiming system, and a vacuum chamber with diagnostic
measuring instruments. The master laser is a YAG crystal (38 mm long rod
4 mm in diameter), replaceable with an Nd-glass rod (306 mm long and 12 mm
in diameter), emitting nanosecond pulses with regular "low-frequency"
modulation and irregular "high-frequency" modulation. The pulse shaper
is a high-speed Kerr-effect shutter. The spectral composition of laser
radiation is measured and controlled by means of a Fabry-Perot etalon and
an MDR-2 monochromator with 4.0 nm/mm dispersion in the 1.06 µm band.
Brightness-energy characteristics of power lasers, including beam divergence
and directivity, energy contrast, pulse shape and pulse duration, were
measured with this facility for optimization of the optical system. Ex-
periments were also performed for determining the dynamics of propagation
of strong shock waves, particularly under conditions of ionization and
dissociation, the results having been correlated with theoretical ones
based on energy balance and an equation of motion as adiabatic process.
Dependence of the shock wave dynamics on the wavefront structure has been
established on this basis. Plasma temperature and evaporated plasma mass
during the initial stage of shock wave propagation were determined experi-
mentally, after gas substance and gas pressure as well as method of record-
ing the position of a shock wave had been suitably selected on the basis
of theoretical considerations, with subsequent evaluation of random and
systematic errors. Following these preliminary experiments, the main
experiments were performed in a study of controlled laser-driven fusion
using targets in the shape of spherical shells. Absorption of laser energy
by such targets was measured by two calorimetric methods, the first involv-
ing measurement of the total laser energy entering the vacuum chamber as well
as the energy lost in refracted and bypassing radiation, the second involv-
ing the use of two high-sensitivity probes, an open and a closed one, whose
readings are compared. The second method was found to be particularly
suitable and sufficiently accurate for determining the energy balance during

heating of spherical targets. Energy absorption by the plasma was also
determined from the shock wave dynamics in an atomic gas, with appropriate
evaluation of experimental data on the basis of thermogasdynamic laws.
Scattering of laser radiation by the plasma was measured on the fundamental
frequency of radiation as well as on its two harmonics, interaction of
laser radiation with the plasma corona found to generate a second-harmonic
spectrum at a critical radiation flux density $q_0 \simeq 10^{13}$ W/cm^2 and a 3/2-
harmonic spectrum at a critical radiation flux density $q_0 \simeq 10^{14}$ W/cm^2.
Finally, X-radiation and neutron radiation emitted by the plasma of such
targets were studied by methods of X-ray photography and obscurogram pro-
cessing. Profiles of plasma density and electron temperature in the corona
as well as the rate of plasma compression were determined on the basis of
these X-radiation measurements. Figures 47, tables 5, references 218:
114 Russian, 104 Western.
[42-2415]

CONTROL COMPUTERS AND EQUIPMENT IN SUBSYSTEMS FOR AUTOMATION OF 'DEL'FIN'
FACILITY

ALLIN, A. P., BELEN'KIY, Yu. M., BORZYAK, Yu. V., BYKOVSKIY, N. Ye.,
GRIGOR'YEV, V. Ye., GUSYATNIKOV, B. S., DOROSHKEVICH, I. L., IVANOV, V. V.,
KUCHINSKIY, A. G., SAVCHENKO, V. M., SEMENOV, V. F., SENATSKIY, Yu. V.,
SKLIZKOV, G. V., SUBBOTIN, L. K., TARANCHUK, V. B., SHPILEVOY, B. N.,
YUZHAKOV, A. N. and YAKUSHEV, A. K.

[Abstract] An automation system is being developed for the "Del'fin"
multibeam Nd-laser equipment operating at the Laser Plasma Laboratory of
Lebedev Physics Institute and capable of producing nanosecond pulses of 10^4 J
energy for experiments with laser-driven fusion. This automation system
has a three-level architecture, with a central computer at the upper (third)
level, at least three subsystems ("laser power supply", "laser beam adjust-
ment", "laser parameters diagnosis") with a computer in each at the middle
(second) level, and each subsystem computer interfaced with at least two
local computers at the lower (first) level. The model for this system was
the U.S. SHIVA facility at Lawrence Livermore Laboratory, the most highly
automated facility of this kind. The "Del'fin" automation system includes,
accordingly, a control computer complex with appropriate software in a
central-panel and ring-series SH trunk with CAMAC peripheral equipment.
The CAMAC equipment has been laid out and built by three firms: "Polon"
(Poland), "Nuclear Enterprise" (United Kingdom) and "HENESA" (Switzerland).
Two RDR-11/04 minicomputers constitute the base of the complex at the
second level. The central computer, with a 28 K 16-word direct-access
memory, an RK-05 2x2.5 Mbyte disk memory and an RX-01 2x256 kbyte flexible-
disk memory, also a TM-11 magnetic-tape memory, operates with two alphanumeric

displays (VT-340 and LYNWOOD), a KE-11B arithmetic unit, a DL-180 matrix
terminal and a DECWRITER terminal. Software can be programmed in FORTRAN-
4, BASIC-11, or COBOL. Automation of the laser power supply involves the
multichannel capacitor bank and the amplifier module consisting of a pre-
amplifier, power stages, and three output stages in tandem, Automation
of the laser beam adjustment involves the optical channel and space-angle
orientation of the optical components as well as the target feed into the
focal space. The aiming command module here can operate in four modes:
with signals from three variable precision resistors on the target drive,
with signals from coordinate photoreceiver heads, with commands from a
computer, and with signals from terminal cutout switches letting the target
move into extreme position along any of three coordinate axes, The latest
trends in further improvement of this control computer complex are toward
use of an SM-4 computer with 124 K direct-access memory at the upper level,
use of "smart" crates on microcomputer (Elektronika-60) base at the lower
level in various configurations most suitable for given function within
given subsystem, use of optical communication lines, and use of satellite
module for electric-to-optical and optical-to-electric signal conversion.
Figures 31, tables 2, references 22: 16 Russian, 6 Western.
[42-2415]

AMPLIFIER MODULE IN 'DEL'FIN' EQUIPMENT FOR HEATING THERMONUCLEAR PLASMA

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KALASHNIKOV, M. P., KRUGLOV, B. V., MIKHAYLOV, Yu. A., OSETROV, V. P.,
PUZYREV, V. N., RODE, A. V., SAVCHENKO, S. M., SKLIZKOV, G. V.,
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[Abstract] The "Del'fin" thermonuclear equipment for heating of targets
in a spherical configuration consists of four functionally independent
high-power amplifier modules, each forming 54 laser beams 45 mm in diameter
with the possibility of combining them into various groups. Subnanosecond
laser pulses are generated in neodymium glass with periodic Q-switching
and high-precision mode locking. Nanosecond pulses are formed by a single-
mode master laser with special electrooptic Kerr shutters. Pulses pass
through a linear preamplifier cascade with filters containing dye solution
and irised space filters inside spherical or cylindrical collimators. This
preamplifier cascade forms a laser beam in pulses of 30-40 J energy and
2.4 ns duration. This beam is split into four, in two steps, each of
which is then boosted to the energy level of the orginal beam. All four
are sent into an amplifier module, one module consisting of a preliminary
stage, a power stage of 3 cells, a power stage of 6 cells, three power stages
in tandem of 6 cells each, and three output stages in tandem of 18 cells

each, with beam splitting between stages effected by means of cylindrical
collimators. Accordingly, 3x18=54 beams appear at the output of an ampli-
fier module and they can, after optical compensation of path lengths and
with focusing, be variously grouped together. Diagnostic equipment includes
calorimeters for measurement of radiation energy, photographic recording
instruments (near field), divergence measuring instruments (far field),
coaxial photocells for measurement of pulse shape, and semiconductor-type
detectors for measurement of energy contrast. Each focusing channel in the
target chamber consists of a multiprism mirror, a long-focus first lens,
a deflecting plate, a rotatable mirror for conforming to spherical target
geometry and for tautochromization, and a short-focus second lens before
the target. Laser radiation is concentrated on the target by means of this
focusing and an aiming system, a test-target mirror serving as monitor
with television hookup. Measurements showed the distribution of radiation
intensity over sections in various beams along the amplifier module, the
structure of light spots, the dependence of beam divergence on energy out-
put of the active medium of an amplifier cell and on the time interval be-
tween successive laser flashes. At a pumping energy of 25 kJ for each
amplifier cell (rod 560 mm long and 45 mm in diameter), the amplifier
module can deliver a total laser energy of 1000 J in 54 beams and pulses
of 2.4 ns duration, with a flux density of 0.6 GW/cm^2, a brightness of 10
10^6 $GW/(cm^2 \cdot sr)$ and with an emission divergence of $3.9 \cdot 10^{-4}$ rad. An experi-
ment with heating of plasmas was performed for the purpose of determining
the performance of such an amplifier module as well as the relation be-
tween structure of the target plasma and parameters of the laser radiation.
Aluminum foil 0.5-10 μm thick and SiO_2 spherical shell segments 100-300 μm
in diameter were used as targets. Heating, in terms of temperature and
plasma density, was monitored through bremsstrahlung and recombination
radiation spectra, also through photography of a plasma in its intrinsic
X-radiation and through relative intensities of components in multiple-
charge ion spectra. Figures 21, table 1, references 30: 15 Russian,
15 Western.
[42-2415]

ACCELERATION OF $_{12}C^{3+}$ IONS FROM LASER PLASMA IN CYCLOTRON

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KOZYREV, Yu. P., KOLESOV, I. V., KUTNER, V. B., OGANESYAN, Yu. Ts.,
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[Abstract] The feasibility of producing a laser source of ions was
established in 1969 (USSR patent disclosure No 324938, BYULLETEN'
OIPOTZ No 7, 1974) and the feasibility of using it in a cyclotron was
established in 1973. An orginal experiment was subsequently performed
with such an ion source and a complete cycle of ion acceleration. Radiation

pulses of 0.4 J energy emitted from a CO_2-laser with transverse discharge at a repetition rate of approximately 1 Hz were injected into a U-200 isochronous cyclotron through a vertical channel in the pole piece of the electromagnet and focused on a target at the center of the cyclotron so as to produce a radiation flux density of the order of 10^9 W/cm^2 at the surface of the latter. Carbon ions $_{12}C^{3+}$ were selected as most suitable for such an experiment. The integral ion current at the output of the source was 1-3 A, with a density of approximately 10 A/cm^2, in pulses of approximately 2.5 µs duration and thus much longer than the laser pulses (evidently as a result of a shift of the energy spectrum of ions toward lower energy during passage of the plasma from target to emission slot and cutting magnetic lines of force in the process). The fast-ion current was approximately 1 mA with $(1-3) \cdot 10^9$ ions per laser pulse at a distance of 30 cm from the cyclotron center, the duration of a fast-ion pulse being 1.5 µs. The intensity of the ion beam impinging on the foil at the cyclotron output was, after charge transfer, $(4-9) \cdot 10^8$ ions per laser pulse. The authors thank G. N. Flerov for formulating the problem and constant involvement, also Ye. A. Korchagin and A. G. Pil'kov for technical assistance in setting up the experiment. Figure 1, references 7 Russian. [47-2415]

DIODE SPECTROSCOPY OF SF$_6$ MOLECULES COOLED IN PULSATING JET DURING MANY-PHOTON INFRARED EXCITATION

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[Abstract] Many-photon excitation of SF$_6$ molecules in a strong infrared
laser field and the mechanism of entrainment during interaction were
studied by the method of infrared-infrared double resonance, in an
experiment with a pumping CO$_2$ pulse laser and a probing variable-frequency
PbSnSe-diode pulse laser. This method is characterized by a high spectral
resolution (10^{-3}-10^{-4} cm^{-1}) and by a high sensitivity, the latter allowing
operation at low gas pressures ($<10^{-3}$ mm Hg) and thus in the almost collision-
less mode of excitation. The molecules of SF$_6$ were cooled in a pulsating
jet to a rotational temperature $T_{rot} < 40$ K and a vibrational temperature
$T_{vib} \approx 160$ K. The time delay between pumping and probing laser pulses was
minimized with the pumping radiation and the cooling jet in a coaxial counter-
flow arrangement. The probing radiation was tuned over the 946.3-948.2 cm^{-1}
band at a rate of $(2-3) \cdot 10^{-3}$ cm^{-1}/μs, completely covering the frequency
range of P and Q branches of the $\nu_3 = 1 \leftarrow \nu_3 = 0$ transition. Oscillograms
of the probing-laser absorption spectra, indicating a decrease of absorption
and a transillumination of P(10), P(9) multiplets, revealed a depletion of
the rotational sublevels in the vibrational ground state of an SF$_6$ molecule
by radiation pulses from the CO$_2$ pumping laser. The fraction of molecules
excited from individual rotational sublevels (and of those remaining
unexcited) was measured as a function of the pumping pulse energy density
over the 0.01-1.3 J/cm^2 range, also as a function of the pulse repetition
rate. The pattern of interaction with all rotational states is attributed
to a dominant role of direct many-photon transitions, including high-
order ones, within the range of lower discrete levels. The authors thank
V. G. Koloshnikov and V. S. Letokhov for support and interest, and
A. A. Makarov for helpful discussion of the results. Figures 3,
references 7: 5 Russian, 2 Western.
[45-2415]

OPTOELECTRONICS

ROLE OF ELECTRON INJECTION IN FORMATION OF OPTICAL IMAGES IN $Bi_{12}SiO_{20}$
CRYSTALS

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[Abstract] The dynamics of electric field distribution in a $Bi_{12}SiO_{20}$
crystal of a PRIZ space-time modulator during recording and processing of
optical images are analyzed taking into account the role of electron in-
jection, a characteristic feature being the buildup of the electric field
at the negative electrode with a narrow weak-field region forming deeper
in the crystal. The dipole moment as a function of time is calculated
theoretically on the basis of specimen and field geometry. It is also
determined experimentally from profiles of electric field intensity over the
thickness of a 10x4.5x0.7 mm crystal. These profiles were measured with
the aid of the transverse electro-optic effect, after exposure to recording
light from an He-Cd laser (λ = 441 nm) or a sodium lamp (λ = 589 nm), with
or without ultraviolet intensification controlling the level of electron
injection from transparent wide surface electrodes. The results reveal
several anomalities in the field distribution dynamics associated with
electron injection. As the injection current increases, the steady-state
electric field intensity at the illuminated electrode decreases and the
dip in the field profile shifts toward the negative electrode. At the
same time, the electric field intensity and consequently also the dipole
moment at the positive electrode become nonmonotonic functions of time:
they first decrease to a minimum and then increase. For efficient opera-
tion of the modulator, therefore, a blocking contact is required on the
negative electrode. Figures 4, references 6: 5 Russian, 1 Western.
[49-2415]

PLASMA PHYSICS

USING METHOD OF RESONANT FLUORESCENCE FOR DIAGNOSIS OF PLASMA NEAR WALL
OF DISCHARGE CHAMBER IN 'TUMAN-3' APPARATUS

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[Abstract] The "Tuman-3" apparatus, a tokomak for study of combined
adiabatic plasma compression on inside (radius 25 cm) and outside
(radius 55 cm) by a rising magnetic field, was used for experiments in
diagnosis of a plasma near walls of the discharge chamber by the method
of resonant fluorescence. The walls of the discharge chamber, all metal,
were made of 1.2 mm thick nichrome. The diaphragm was 1-1.2 cm high.
The longitudinal magnetic field was 0.3-0.4 T strong during Joule-effect
heating with a current of 70 kA and reached 0.9 T during adiabatic compres-
sion. The electron concentration was approximately 10^{13} cm^{-3}. Fluorescence
of Fe and Ni atoms near the walls was excited and recorded with special
equipment, from separate levels of the respective fine structures
Fe I α^5D and Ni I α^3F. The minimum recordable concentration of Fe atoms
was $3 \cdot 10^6$ cm^{-3}, the sensitivity of instruments being limited principally
by fluctuations of the photocurrent from the photomultiplier cathode and
the noise of intrinsic plasma flow being several orders of magnitude
weaker than the useful signal. The distribution of Fe-atom concentration
in space and time was measured under conditions of saturated optical
transition, the concentration found to reach the maximum of approximately
$2 \cdot 10^7$ cm^{-3} during the middle stage of discharge in the Joule-effect heating
mode and to decrease appreciably during adiabatic compression. The con-
centration of Ni atoms was also measured by the same method under analogous
conditions, and found to reach a maximum of $(2-3) \cdot 10^7$ cm^{-3}. The authors
thank V. Ye. Golant for interest in this study and the "Tuman-3" staff
for assistance in the experiments. Figures 2, references 3 Western.
[44-2415]

EMISSION OF HIGH-ORDER HARMONICS OF HIGH-POWER LASER RADIATION IN PLASMA

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[Abstract] Emission of high-order harmonics of laser radiation in a plasma
heated by a CO_2-laser is examined from the standpoint of mechanisms which
generate these harmonics. According to the theory of weak nonlinearity,
there is an inverse exponential dependence of the emission intensity on
the order of harmonic. Emission of high-order harmonics in this case of
finite nonlinearity can be effected by a discontinuity mechanism, an
example being umklapp of electron flux resulting in a power-law dependence
of the emission intensity on the order of harmonic. Two illustrations of
this are radiation emitted furing umklapp of a nonrelativistic electron
beam in a homogeneous plasma and emission of even more intense dipole
radiation during collision of an umklapped electron wave with a perturbation
of the ion concentration. References 8: 5 Russian, 3 Western.
[44-2415]

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